A Pilot Study of Trace Metal Mobility During Combustion of Biomass Fuels

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Contractor: University of California, Davis
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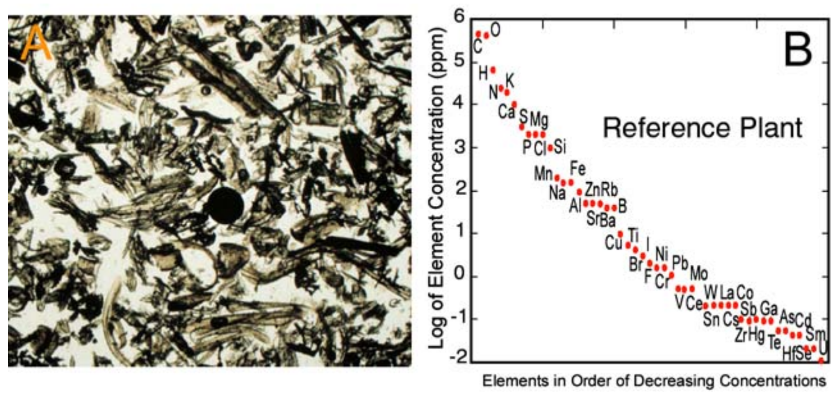
The Issue

Combustion of biomass fuels for power generation produces solid wastes (ash and slag) that concentrate metals and other elements from the original feedstock. Little information exists on trace metal mobility and concentrations in the combustion by-products from power plants fueled by biomass. Such information is essential to the reuse of ash waste products as well as to environmental monitoring and protection.



Left: Rice straw ash produced by firing at 525°C (977°F). Right: Reference plant material with log-scale concentration of elements (parts per million) arranged in order of decreasing concentration.

The need for this information is expected to grow. If biomass fuel consumption increases as forecasted, the power industry will face even stronger pressures to find alternative uses and/or safe storage facilities for the combustion by-products. Additionally, the adoption of advanced conversion technologies for biomass under different reaction conditions than employed in direct combustion systems requires prior knowledge of the content of trace elements in biomass as well as knowledge of their fate during conversion.

Project Description

Funded by PIER's Environmental Exploratory Grants Program, this study determined the trace element concentrations in ashes produced from three common biomass materials. Controlled-temperature experiments were conducted on clean samples of wood, rice straw, and wheat straw to evaluate trace element mobility as a function of firing temperature (from 977°F to near the melting range). A supporting study analyzed the ash products from a commercial operating biomass-fueled power plant and from an intake-controlled fluidized bed combustor.

The concentrations of major and trace elements in ash and slag were analyzed using various multielement techniques: X-ray fluorescence spectroscopy for major and minor elements, inductively coupled plasma mass spectroscopy (ICPMS) for most trace elements, and short-irradiation-duration instrumental neutron activation analysis (INAA) for the alkali metals and chlorine.

PIER Program Objectives and Anticipated Benefits for California

This project offers numerous benefits and meets the following PIER program objectives:

- **Providing environmentally sound energy.** Biomass is a renewable domestic fuel with no sulfur emissions and dramatically lower nitrogen emissions than fossil fuels. Biomass can thus decrease acid rain and smog when used instead of fossil fuels. Net carbon emissions can be reduced, as the emitted carbon can be removed from the atmosphere by growing more biomass. This project yields basic information that is critical to the responsible use of biomass for power generation.
- **Resolving the environmental effects of energy production.** This research will enhance state regulatory monitoring of compliance with solid waste disposal standards. Results will also benefit policy analysts and power producers by enabling prediction of trace element baselines in ash waste as new biomass materials are introduced into the fuel mix, such as those from phytoremediation of impaired soils (use of plants to decontaminate soils). Knowledge of potentially leachable trace elements and their concentrations in biomass ash is necessary for planning and designing short- and long-term storage and disposal facilities as well as for developing alternative utilization strategies. For example, better knowledge of the trace elements in biomass ash can result in a better understanding of the beneficial value of ash by-products as soil fertilizers, potentially increasing the use of biomass ash and reducing the need for its disposal in landfill.

Results

Trace element concentrations in biomass ash are a function of the fuel composition, firing temperature, and firing duration. Compared to the original fuel, element concentrations may become *enriched* due to the removal of volatile constituents, or *depleted* due to trace element removal along with the volatile components. Depletion can be so severe that elements can be completely removed from the solid fraction. Depletion with increasing firing temperature was notable for the alkali metals (sodium, potassium, rubidium, cesium), and could also be seen for other elements (chlorine, silver, cadmium, arsenic, selenium, and lead).

Analysis of the ash from fuel-intake-controlled experiments indicates that (1) strong fractionation occurs during combustion, (2) trace element concentrations can be strongly affected by contamination from plant construction materials such as steel, and (3) urban fuels can strongly affect heavy metal concentrations.

Among the fuel samples tested, enrichment of both barium and lead in wood ash resulted in concentrations slightly exceeding the US Environmental Protection Agency’s total constituent analysis limits for heavy metals. In ashes with a significant component of urban wood, As, Cr, and Pb may exceed EPA limits. Metals in all tested straw ashes were below permitted limits. Leaching of straw ashes also depletes many alkali major and trace elements, although concerns may then arise as to concentrations in water or other solvent employed.

Final Report

The final report for this project can be downloaded from the Energy Commission’s website at www.energy.ca.gov/publications/displayOneReport.php?pubNum=CEC-500-2008-014.

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